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Field Evaluation of Tile Drain Filters in a Humid Region Soil

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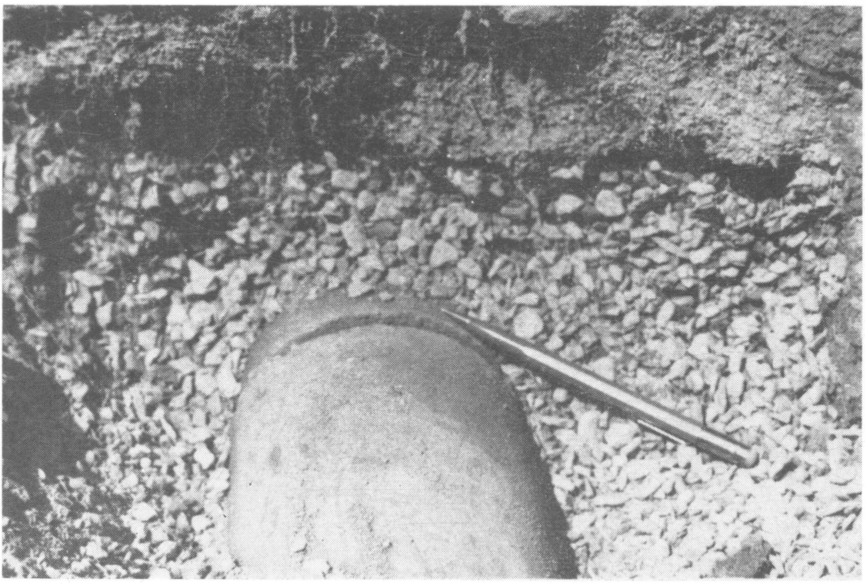

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Field Evaluation of Tile Drain Filters in a Humid Region Soil[1]

GEORGE S. TAYLOR and TRUMAN GOINS[2]

INTRODUCTION

In some parts of the irrigated southwestern United States, coarse sands and gravels are frequently placed over tile drains at the time of their installation. A common practice in Holland is to cover the drains with a layer of peat mulch (4). In practically all countries which utilize underground drains, the tile is blinded with top soil (4).

The primary purpose of these practices is to filter out much of the finer soil particles which may move into the drain during water flow. Another objective is to keep the crack spacing between individual tile drains open so that drain discharge is not reduced. If these objectives are accomplished, the functional life of a drainage system is increased. On the other hand, these practices increase the expense of installation. For example, the cost of adding gravel or organic mulch may be as high as $30 to $50 per acre, depending on the closeness of these materials and spacing between tile lines.

It is generally assumed that filter materials are not needed for tile drains installed in the finer-textured soils of the humid region. In contrast with certain soils of arid regions, for example, the humid region soils are seldom dispersed as a result of high sodium contents. On the other hand, there is visual evidence of siltation in shallow tile lines which were installed some 25 to 30 years ago. It is not known to what extent tile filters may affect such siltation. One purpose of the present study was to provide additional information on this subject.

A second objective was to evaluate the effect of tile filters in reducing the hydraulic impedance at the drains. It is well known, for example, that during water flow into drains some 20 percent of the total hydraulic resistance lies in a small soil region adjacent to the drains (5).

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[1]Acknowledgments are due the following persons for invaluable assistance in this study: Ralph Bazler for aiding in establishment of the experiment; Thomas Jones for making the water table study; and Thomas J. Thiel, Dr. Joe H. Jones, and Dr. Bunyut Vimoke for assisting in the excavation and visual inspection of the tile lines.

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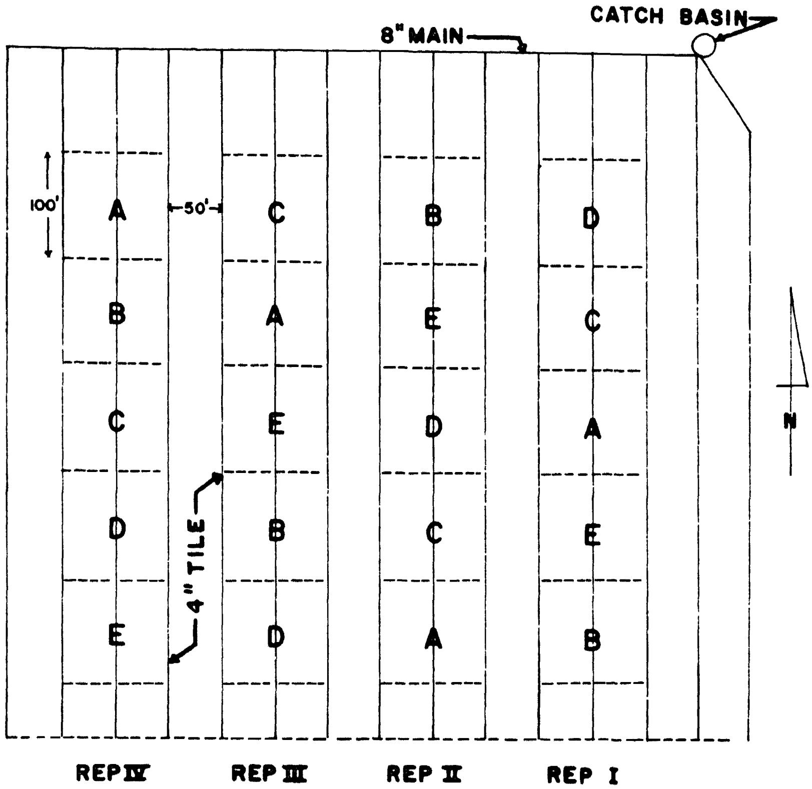
This conclusion is based on studies in which the soil placed around the drain has the same permeability as the undisturbed soil. Since the backfill over a drain is disturbed, it is not known to what extent these results are applicable to field conditions.

Laboratory studies have shown the value of filter materials in reducing sedimentation of drains. Sisson (8) reported that straw and sawdust were effective in preventing sand from entering a lucite drain. These materials were placed around the top and sides of the drain tubes, while the lower one-fourth was in direct contact with a uniform medium



A. NO FILTER
B. CRUSHED STONE
C. VERMICULITE
D. CORNCOBS
E. WHEAT STRAW

Fig. 1.—Experimental area used in the tile filter study, The Ohio State University Airport Farm, Columbus.

sand. Corncobs provided only slightly better protection than no filter. The use of a gravel filter significantly increased the drain flow rate over that obtained with the three organic materials.

Overholt (7) found that glass fiber sheets were beneficial in reducing sedimentation of drains in a sandy soil. The accumulation of silt in unprotected drains was three times greater than in drains where the upper three-fourths was covered with glass fibers. Wrapping glass fibers completely around the drain essentially stopped sedimentation. Drain discharge rates were 1.7 and 2.3 times greater than unprotected tile, respectively, in these two tests.

The results of field tests with drain filters are not as straightforward. In a study with a muck soil, Lyons *et al* (6) reported that safflower straw was more effective than glass fiber mats in increasing tile discharge rates. On the other hand, DeBoer and Johnson (2) found no increase in tile discharge rates when sand and gravel filters were installed around drains in soils high in sand content.

In other studies with organic filter materials around drains, Brownscombe (1) reported little to moderate deterioration of straw after 6 to 11 years. Wood chips showed little deterioration during the same period.

Ford and Beville (3) used calcium silicate slag around drains to precipitate hydrated iron sludge before it enters and subsequently clogs crack spacings between drains. This work was done in sandy soils of Florida and it is not believed that such a practice is needed in soils of the Midwest.

METHODS AND MATERIALS

Filters and Drains: In 1953 the tile drainage system shown in Figure 1 was installed at The Ohio State University Airport Farm, Columbus. The tile lines were uniformly spaced at 50-fot intervals, with a length of 700 feet, an average depth of 3 feet, and a grade of 0.2 percent. Twelve-inch wide trenches were dug with a wheel-type trenching machine and 4-inch clay tile was laid with an approximate crack spacing of 1/8 inch. Before the tile lines were covered, various filter materials were added to the open trench and they settled above and along the sides of the tile lines. The soil excavated from the trenches was then returned to the trenches with a bulldozer. The filter materials were as follows:

A. No Filter: The soil removed during excavation was used to cover the drains and fill the trench.

B. Crushed Stone: This material was crushed limestone which had been washed and screened. Approximately 90% of the stone was in the size range of 1/4 to 1/2-inch diameter. The stone covered the tile line to a depth of 3 inches.

C. *Vermiculite*: Commercially available vermiculite was used at a rate of 17 cubic feet per 100 feet of tile line. At the time of application, the vermiculite extended approximately 3 inches above the tile line.

D. *Corncobs*: The corncobs were from the previous season's harvest. They had been run through a mechanical sheller and ranged in length from 1 to 4 inches. At the time of application, the tile line was covered to a depth of about 6 inches.

E. *Wheat Straw*: Straw from the previous season's crop was used to fill the trench about half full in an unpacked condition. It was packed by tramping under foot and then covered the tile line about 6 inches.

Procedure: Following initiation of the experiment in 1953, the annual sequence of cropping was corn, barley, wheat, clover-alfalfa (2 years), corn, oats, and clover-alfalfa. No experimental measurements were taken until 4 years later (1957), at which time the area was first in clover-alfalfa.

At this time, 3/4-inch perforated pipe was installed at an average depth of 4 feet and at horizontal distances of 0, 2, 6, and 25 feet from the tile lines. The pipe at 0 feet was adjacent and touching the tile drains. The pipes were installed in a line which was at right angles to the tile lines and midway across each plot. There were four water table pipes per plot, making a total of 80 in the experimental area. Water table elevations were measured frequently during March, April, and May of 1957. These data were subjected to an analysis of variance to analyze statistically the differences among treatments.

In 1961, 8 years after the experiment was initiated, the tile lines were visually inspected by excavating a 3-foot section of tile line in each plot. Excavation was accomplished by digging to a few inches above the tile lines with a backhoe and then further removing the backfill with hand tools. Photographs were taken and observations were made on the condition of the tile lines.

Soil: The experimental site is located on an undulating till plain area having an average slope of 1 percent. The soil is Crosby silt loam which has developed from calcareous loam till. Its textural analysis is given in Table 3. The percentage of silt is highest in the A horizon and fairly constant in the B and C horizons. The clay content is highest in the upper B horizon. The A horizon has a weakly aggregated granular structure; the upper B horizon, a moderate medium subangular blocky structure; and the C horizon, a weak coarse subangular structure. The organic matter content is 2.7 percent in the A horizon and 0.8 percent in the upper B.

The Crosby series represents the somewhat poorly drained toposequence member of the well-drained Miami, moderately well-drained Celina, and poorly drained Brookston sequence. These soils occur extensively in west central Ohio and are estimated to comprise a little more than 2 million acres or about 8 percent of the total land area in the state. They also occur in Indiana, Michigan, Wisconsin, and Illinois.

The cohesive forces which bind individual soil particles into relatively stable aggregates are of high magnitude due to the fine textures (38 to 45 percent clay) and the cationic status (dominantly H^+, Ca^{++}, and Mg^{++}) of these subsoils. The latter is conducive to a flocculated condition rather than to a dispersed condition which is found in some irrigated soils high in exchangeable sodium. The moderate, subangular blocky structural units of this soil are relatively water stable, even under disturbed conditions.

RESULTS

Water Table Elevations: The most complete information on water table levels was obtained during the period April 3-28, 1957, and only these data are presented (Table 1 and Figure 2). There were 6.1 inches of rainfall in April and more than half of this amount occurred during the first 5 days (Table 2). The average April rainfall for this site is 3.5 inches. Although tile discharge rates were not measured, visual inspection of the catch basin showed that water flowed in the tile main during most days of this month.

The filter materials had little influence on water table drawdown. Differences in water table elevations among the various filter treatments were not statistically significant at the 2 and 25-foot distances from the drains (Table 1). At the drain, differences in water table elevations were statistically significant for approximately half of the measurement dates. The magnitude of these differences was only 0.1 to 0.2 feet. The highest water table levels generally occurred in the treatments receiving crushed stone, vermiculite, and no filter. At a distance of 6 feet, differences among water table elevations were statistically significant for most of the measurement dates. For this distance, the water table level in the no-filter treatment was significantly lower than in all others.

The water table surfaces for the period April 18-29 are illustrated in Figure 2. Only the results for two treatments are shown since the others are quite similar to those for the crushed stone filter. The drawdown surfaces are fairly steep near the drain, particularly when the

TABLE 1.—Water Table Elevations at Various Dates During the Period April 3-29, 1957. The Ohio State University Airport Farm, Columbus. Each Value Represents the Average of Four Measurements.

Distance from Tile (Feet)	Water Table Elevation Above Base of Tile (Feet)					Signif- icance Level (†)	LSD (.05 Level)
	No Filter	Crushed Stone	Vermi- culite	Corn- cobs	Wheat Straw		
			1130 April 3				
0	0.2	0.3	0.1	0.1	0.1	**	0.1
2	1.0	1.2	1.2	1.2	1.1	NS	—
6	1.3	2.0	2.1	2.3	2.1	*	0.4
25	2.5	2.7	2.7	2.6	2.7	NS	—
			1310 April 4				
0	1.0	0.7	0.8	0.4	0.5	NS	—
2	2.7	2.4	3.1	2.3	2.8	NS	—
6	2.9	3.1	3.3	3.2	3.1	NS	—
25	3.1	3.1	3.2	3.2	3.3	NS	—
			0100 April 5				
0	0.3	0.3	0.3	0.2	0.2	*	0.1
2	1.9	2.0	1.9	1.9	2.0	NS	—
6	2.0	2.5	3.2	2.9	2.6	**	0.3
25	2 9	3.2	3.2	3.2	3.1	NS	—
			0950 April 5				
0	0.3	0.3	0.3	0.1	0.1	NS	—
2	1.5	1.8	1.9	1.8	1.7	NS	—
6	1.9	2.7	3.0	2.8	2.7	**	0.3
25	2.9	3.1	3.1	3.1	3.1	NS	—
			1540 April 5				
0	0.3	0.3	0.4	0.3	0.1	NS	—
2	2.1	2.0	2.6	1.9	2.3	NS	—
6	2.3	3.0	3.2	3.1	3.0	**	0.3
25	3.0	3.2	3.2	3.2	3.2	NS	—
			1625 April 9				
0	0.3	0.3	0.3	0.1	0.1	*	0.1
2	1.6	1.9	2.0	1.7	1.8	NS	—
6	2.0	2.7	3.0	2.8	2.7	*	0.4
25	2.9	3.1	3.1	3.1	3.1	NS	—
			1500 April 18				
0	0.4	0.4	0.5	0.2	0.2	**	0.1
2	2.3	2.4	3.1	2.0	2.5	NS	—
6	2.8	3.0	3.2	2.9	3.1	NS	—
25	3.0	3.2	3.3	3.2	3.2	NS	—

†Statistical significance at 0.05 and 0.01 levels are indicated by one star (*) and two stars (**) respectively. Non-significance is indicated by the letters NS.

TABLE 1. (Continued)—Water Table Elevations at Various Dates During the Period April 3-29, 1957. The Ohio State University Airport Farm, Columbus. Each Value Represents the Average of Four Measurements.

Distance from Tile (Feet)	Water Table Elevation Above Base of Tile (Feet)					Significance Level (†)	LSD (.05 Level)
	No Filter	Crushed Stone	Vermiculite	Corncobs	Wheat Straw		
			0715 April 19				
0	0.3	0.3	0.3	0.1	0.1	*	0.1
2	1.5	1 6	1.8	1.5	1.6	NS	—
6	1.7	2.5	2.8	2.5	2.5	*	0.4
25	2.8	3.0	3.0	3.0	3.0	NS	—
			1330 April 19				
0	0.3	0.3	0.3	0.1	0.1	*	0.1
2	1.4	1.5	1.7	1.4	1.5	NS	—
6	1.5	2 3	2.6	2.5	2.4	*	0.4
25	2.7	2.9	2.9	2.9	2.9	NS	—
			0900 April 20				
0	0.2	0.3	0.2	0.1	0.1	NS	—
2	1.0	1.1	1.3	1.1	1.2	NS	—
6	1.3	1.8	2.1	2.1	1.8	*	0.3
25	2.4	2.5	2.5	2.5	2.6	NS	—
			1140 April 21				
0	0.2	0.3	0.2	0.1	0.1	NS	—
2	0.7	0.9	1.0	0 8	0.9	NS	—
6	1.0	1.4	1.6	1.6	1.5	*	0.3
25	1.9	2.1	2.0	2.0	2.1	NS	—
			1645 April 22				
0	0.1	0.2	0.2	0.0	0.1	NS	—
2	0.5	0.8	0.8	0.7	0.8	NS	—
6	0.8	1.3	1.5	1.5	1.3	*	0 3
25	1.8	2.1	2.1	2.1	2.1	NS	—
			1510 April 25				
0	0.1	0 2	0.2	0.0	0.1	NS	—
2	0.3	0.6	0.7	0.5	0.6	NS	—
6	0.6	1.1	1.2	1.2	1.1	*	0.3
25	1.4	1.8	1.6	1.5	1.6	NS	—
			1055 April 29				
0	0.1	0.2	0.1	0.0	0.0	NS	—
2	0.2	0.4	0.4	0.3	0.4	NS	—
6	0.3	0.6	0.6	0.7	0.5	NS	—
25	0.8	1.1	0.8	0.8	0.9	NS	—

†Statistical significance at 0.05 and 0.01 levels are indicated by one star (*) and two stars (**) respectively. Non-significance is indicated by the letters NS.

mean water table is close to the ground surface. The curvature of the water table surfaces is representative of those found in tile-drained humic gley soils of northern Ohio (9).

Visual Inspection of Drains: Eight years after the experiment was initiated, 18 pits were dug to observe the condition of soil and filter materials at the drains and to inspect the tile lines. The wheat straw and corncobs had virtually disappeared, leaving approximately a ½-inch residue around the upper two-thirds of the drain (Figure 3). The

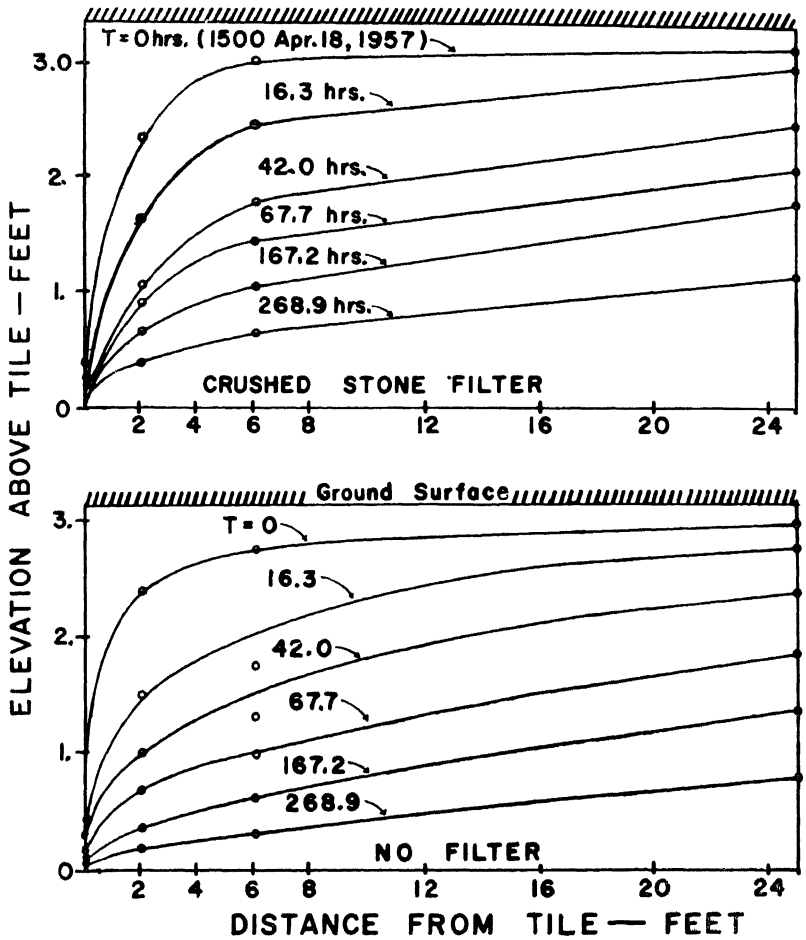


Fig. 2.—Water table elevations in two plots at various times during April 18 and 19. Each curve represents the average water table position in the four replicate plots. The upper four curves in each graph give the water table levels during a rain-free period.

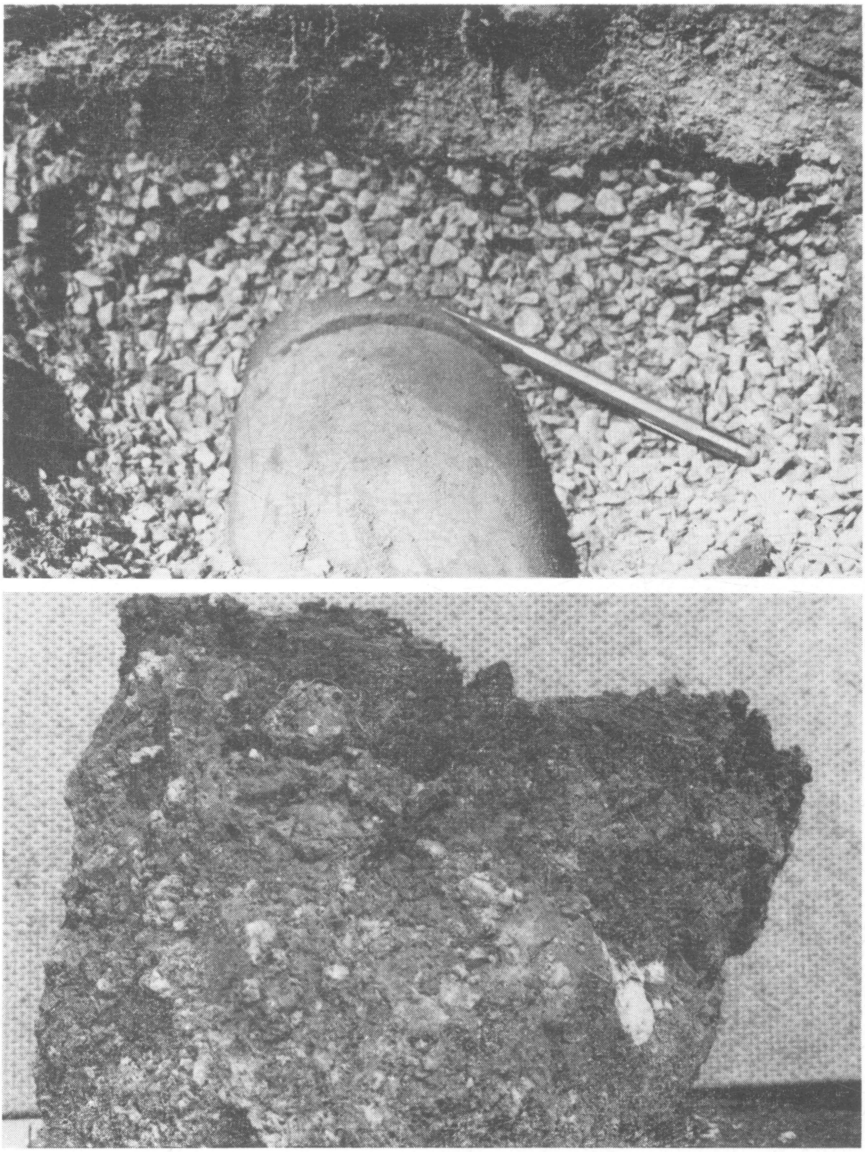


Fig. 3.—Crushed stone filter material 8 years after installation (upper photo). The lower photo shows the small amount of wheat straw residue remaining after the same time period. The straw residue was originally resting directly above the drain and is inverted in the photo.

TABLE 2.—Rainfall for April 1957. The Ohio State University Airport Farm, Columbus.

Date	Rainfall (in.)	Date	Rainfall (in.)
April 1	0.81	April 16	0.27
April 2	0.11	April 17	——
April 3	1.10	April 18	0 38
April 4	1.05	April 19	——
April 5	0.47	April 20	——
April 6	——	April 21	——
April 7	——	April 22	0.60
April 8	0.68	April 23	——
April 9	——	April 24	——
April 10	0.12	April 25	——
April 11	——	April 26	——
April 12	——	April 27	0.19
April 13	——	April 28	0.32
April 14	——	April 29	——
April 15	——	April 30	——

straw residue was porous and matted and the corncob residue was granular. A number of earthworms were found in the latter. The reduction in volume of these residues caused the backfill to settle 2 to 3 inches during the first 3 years of the experiment.

The crushed stone appeared to be unchanged from the time of its application and was essentially free of soil (Figure 3). The vermiculite was compressed into a ½-inch band and it was also free of soil. In the plots which received no filter material, the soil directly above and touching the drains showed evidence of previous puddling (Figure 4). This condition was also observed in the soil directly above the filter materials but was less pronounced than in the plots without a filter.

Two conditions were consistent among all treatments: 1) All of the tile lines were essentially free of sediments. Sediments were found only at the junction of individual drains where there was slight departure from tile alignment. 2) The soil adjacent to the drain and in the horizontal plane showed extensive channeling (Figure 5). These channels were ⅛ to ¼ inch in diameter. The peripheries of the channels were smooth, obviously from the flow of water through them. The channels did not appear to originate from shrinkage cracks. Rather, they seemed to result from incomplete settling of the soil. This condition could be caused by reduced overburden pressure around the sides of the drains due to bridging of the backfilled soil along the trench walls.

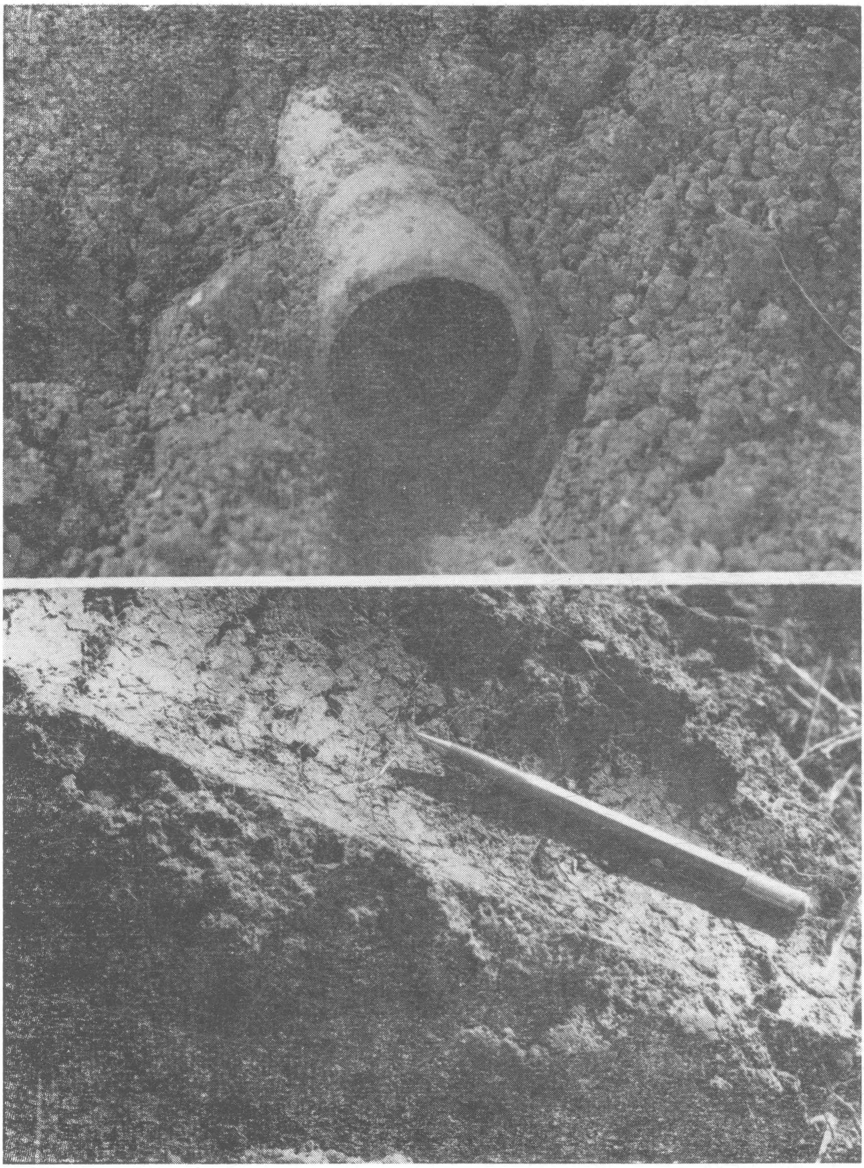


Fig. 4.—The upper photo shows the small amount of sediment in a drain which did not receive filter material. The lower photo shows the condition of subsoil backfill which was in direct contact with the upper part of the drain. In the latter, the soil is inverted from its original position. Both photos were taken 8 years after tile installation.

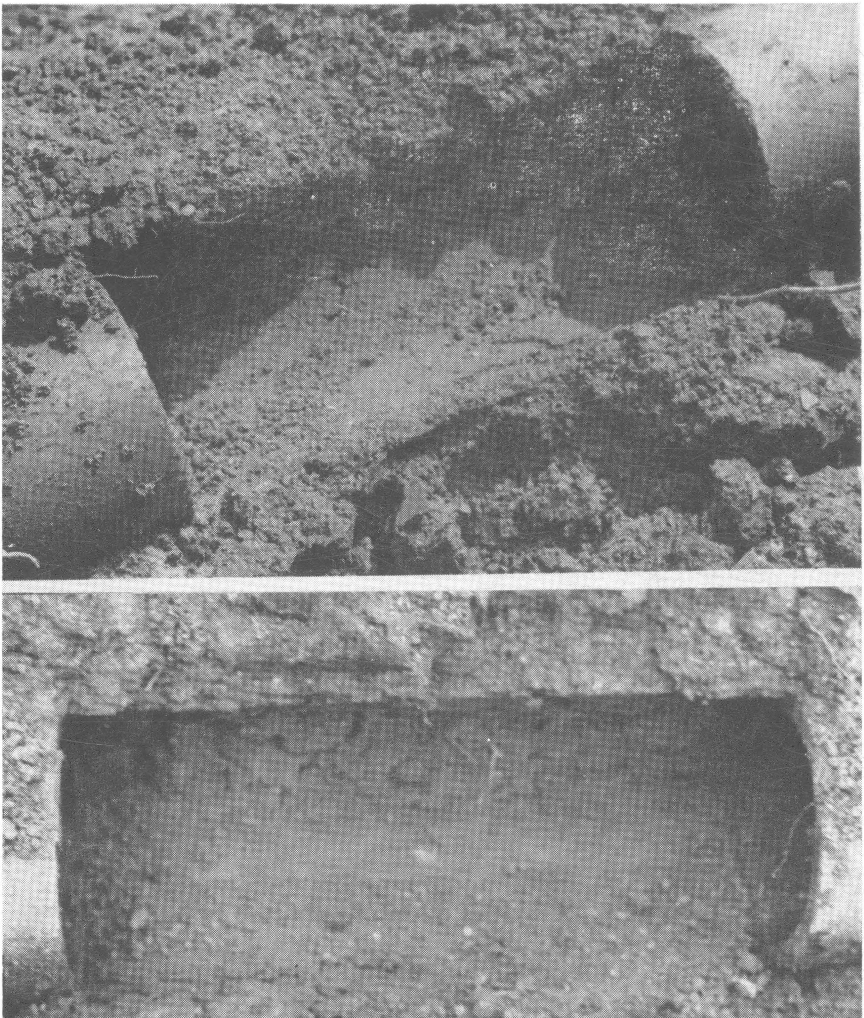


Fig. 5—Two views of the soil surrounding the lower half of a 1-foot drain tile. Note the numerous channels and cavities along the horizontal plane which passes through the drain center. These drains did not receive filter material. The photos were taken 8 years after tile installation.

The porousness of the soil adjacent to the drain varied, depending on whether the soil was originally from the plow layer or the subsoil. After 8 years, topsoil could still be identified by its darker color and it was more porous than subsoil. It was also observed that subsoil directly above the drains in some pits was considerably more compacted than subsoil in others. The compacted soil could have occurred when wet subsoil caved in prior to backfilling the trenches. If this were true, the wet soil could have puddled more than the drier subsoil which was placed over the drains at a later date.

Sediment from Tile Drains: A mechanical analysis of the sediment was made and these results are shown in Table 3, along with the soil mechanical analysis. The sediment was higher in silt and lower in sand than any of the soil horizons. Its mechanical analysis resembles that of the A horizon more than any other horizon. It does not necessarily follow, however, that the sediment originated from the plow layer. The sediment may have originated from the B or C horizon and its composition could have been altered by sorting during transport.

The average specific gravity of minerals in each soil horizon and in the sediment was also determined. There was only a small range among these values and it was not possible to associate minerals in the sediment with those from a particular soil horizon. A similar analysis of organic matter contents was also unsuccessful. The color of the sediment was intermediate between that of the dark surface soil layer and the gray subsoil horizons.

DISCUSSION

There is some doubt as to the validity of the water table measurements taken at 0 foot from the drain. This measurement may only evaluate the resistance of water flow from the water table pipe to the

TABLE 3.—Textural Analysis of Crosby Silt Loam and Sediment from Tile Drains. The Ohio State University Airport Farm, Columbus.

	Particle Size Distribution (Percent)		
Horizon and Depth	Sand (2-.05 mm)	Silt (50-2μ)	Clay (< 2μ)
		Crosby Silt Loam	
A(0-8")	17	61	22
B(8-14")	9	46	45
B(14-25")	17	45	38
C(25-44")	30	42	28
		Sediments from Drains	
—	7	66	27

drain. Thus, the water table at the drain may be higher than indicated in Table 1 and Figure 2. Regardless of this uncertainty, the low water table elevations indicate low hydrostatic pressure in the near vicinity of the drain. Otherwise the water would not quickly drain from the water table pipes.

Overall, it appears that the filter materials had little influence, if any, on water table drawdown by the tile drains. It is true that the mean water table elevation at 0 and 6 feet from the drains was significantly different among the filter treatments on several measurement dates. However, these differences must be interpreted in light of all of the data.

First, differences among water table elevations as small as 0.1-0.2 foot are within experimental error. Thus, the differences in water table levels at 0 foot from the drain probably have no real significance. It matters little that the differences at this distance are statistically significant. Such significance may also reflect consistency in these measurements and the mean water table levels may have been consistently in error by 0.1 or 0.2 foot. This might be due, for example, to small discrepancies in establishing drain and water table pipe elevations.

Second, if the no-filter treatment resulted in a lower water table than the filter treatments at 6 feet from the drain, it would appear that this relationship should hold at 0, 2, and perhaps 25 feet from the drain. This was not the case for any of the 14 measurement dates.

Third, the sharp decline of the water table near the drain in all treatments suggests that the impedance in the backfill and at the drain crack spacing was not the limiting factor in drawdown (Figure 2 and Table 1). For example, a high water table at the drain would suggest either back pressure inside the drain or a large hydraulic impedance at the tile crack spacings or in the soil adjacent to the drain. Apparently none of these conditions could have prevailed for any appreciable length of time.

It is difficult to give an adequate explanation for the low water table elevations observed in the no-filter plots at 6 feet from the drain. A probable explanation is that they were due to "location effects." Such location effects as a slightly higher ground surface elevation or a lower water infiltration rate could have been contributing factors. These factors are usually averaged out by random selection of the treatment sites and by replication. However, this may not have been the case in this experiment.

One can only speculate concerning the reason for so little improvement in drawdown as a result of adding filter materials around the drains. It is believed that the cohesive and aggregating nature of this soil was a major factor. First, the soil is relatively well aggregated and the individual soil particles are not easily detached by water. Thus, there would be little sediment to clog the drain crack spacings and to settle in the tile lines. Second, the cohesive nature of the soil is large enough to provide some bridging around the drain. This prevents complete settlement and compaction along the walls of the drain and apparently permits the formulation of cracks and channels in the soil around the drains (Figure 5). The effect of such water-conducting channels is to reduce the soil hydraulic impedance adjacent to the drain. This would lower the flow velocity in this region and thus decrease the sediment-carrying capacity of the inflowing water. Because of the lower hydraulic impedance, there would be little influence of the filter material on tile flow rates and water table drawdown.

What beneficial effects, if any, would the filter materials have on tile systems in this soil after 15 to 25 years? Unfortunately, this question cannot be answered from these findings. It has been observed, for example, that shallow drains (about 18 inches deep) in this and similar soils become partially filled with sediment after 20 to 25 years. It would appear that a shallow drain might have more sediment deposits than a deeper one. Sediment-laden water would percolate through a smaller volume of soil and there would be less filtration of the sediments. Old tile systems in this area of Ohio are also characterized by shallow outlets and small grades; these conditions have undoubtedly encouraged greater sediment deposits.

The results of this study cannot be applied to sandy soils. Such soils are slightly cohesive, if at all, and the individual sand grains are easily detached by running water. In some areas of the irrigated Southwest, sand and gravel filters are used rather extensively for drains in sandy soils.

The observations made on tile drains and backfill following 8 years of farming operations suggest the following. It appears that a good practice is to spade or plow a covering of topsoil over the tile lines before the trench banks cave in or the subsoil excavation is returned to the trench. For example, it was noted that when topsoil had been put directly over the drains, the soil was more porous. Perhaps the use of topsoil aids in the formation of natural water channels to the drains. Unfortunately, there was no means other than visual observations to establish the superiority of topsoil over subsoil for backfilling directly over the drains. Thus, the above practice can only be suggested from the findings of this study.

SUMMARY

The objective of this study was to determine the benefits of placing permeable materials around tile drains. Various filter materials were placed over recently installed tile drains in a Crosby soil at The Ohio State University Airport Farm, Columbus. These materials were corncobs, wheat straw, crushed stone, and vermiculite. Approximately 3 to 6 inches of each material were applied directly over the drains and then the tile trenches were backfilled with the excavated soil. Other tile drains received no filter materials.

From the results of a water table study made 4 years after installation, the use of filters did not reduce the time required for water table drawdown. In a visual evaluation made 8 years after tile installation, only negligible amounts of sediment were found in any of the tile drains. The soil adjacent to all drains was found to be in a porous condition, regardless of filter treatment. Apparently this soil has rather water-stable aggregates and consequently does not contribute significantly to siltation of the drains or to severe soil settlement around the drain.

Filter materials are not recommended for agricultural drains in silty and clay-textured soils of the humid region. The results of the present study do not challenge this position.

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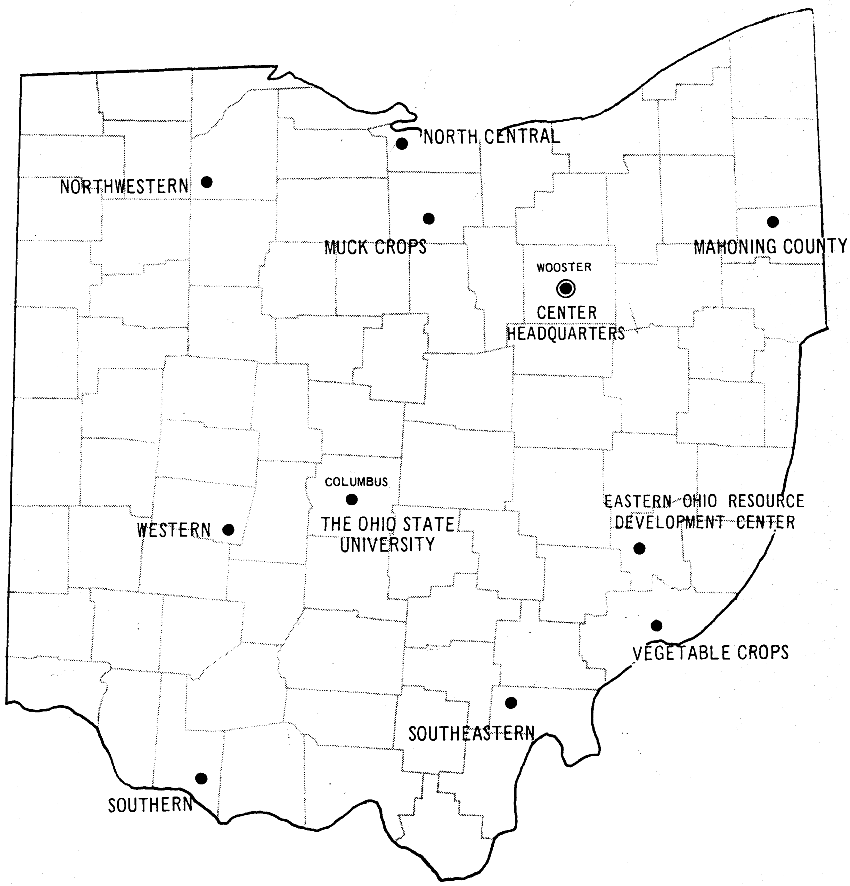

Ohio's major soil types and climatic conditions are represented at the Research Center's 11 locations. Thus, Center scientists can make field tests under conditions similar to those encountered by Ohio farmers.

Research is conducted by 13 departments on more than 6000 acres at Center headquarters in Wooster, nine branches, and The Ohio State University.

Center Headquarters, Wooster, Wayne County: 1918 acres
Eastern Ohio Resource Development Center, Caldwell, Noble County: 2053 acres
Mahoning County Experiment Farm, Canfield: 275 acres
Muck Crops Branch, Willard, Huron County: 15 acres
North Central Branch, Vickery, Erie County: 335 acres
Northwestern Branch, Hoytville, Wood County: 247 acres
Southeastern Branch, Carpenter, Meigs County: 330 acres
Southern Branch, Ripley, Brown County: 275 acres
Vegetable Crops Branch, Marietta, Washington County: 20 acres
Western Branch, South Charleston, Clark County: 428 acres